



Spiteri, T., Vafiadis, G., & Nunez-Yanez, J.L. (2009). A toolset for the analysis and optimization of motion estimation algorithms and processors. In *International Conference on Field Programmable Logic and Applications, 2009 (FPL 2009), Prague* (pp. 423 - 428). Institute of Electrical and Electronics Engineers (IEEE).
<https://doi.org/10.1109/FPL.2009.5272247>

Peer reviewed version

Link to published version (if available):
[10.1109/FPL.2009.5272247](https://doi.org/10.1109/FPL.2009.5272247)

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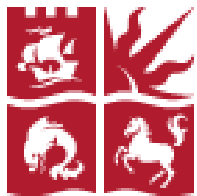
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2009-09-02

A Toolset for the Analysis and Optimization of Motion Estimation Algorithms and Processors

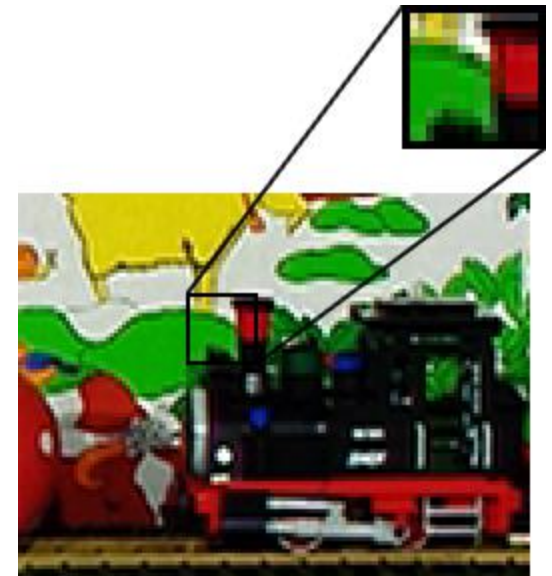


University of
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Department of Electrical and
Electronic Engineering

Overview

- Motion estimation takes time, full search expensive for HD.
- Flexible reconfigurable processor.
- IDE to design and test algorithms.
- Toolset to configure the processor.

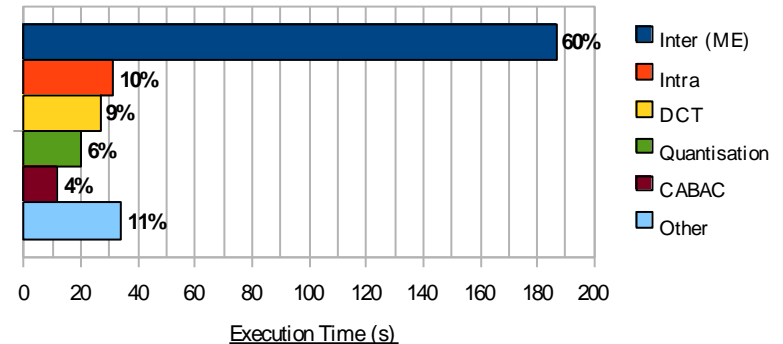


Saving time

- Motion estimation takes processor time.
- The design space to explore is large.
- Configuring the ME processor takes developer times.

Execution Time Distribution

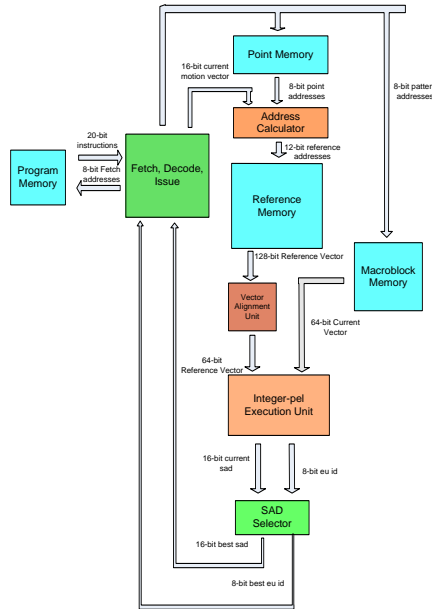
720p pedestrian, baseline, noasm



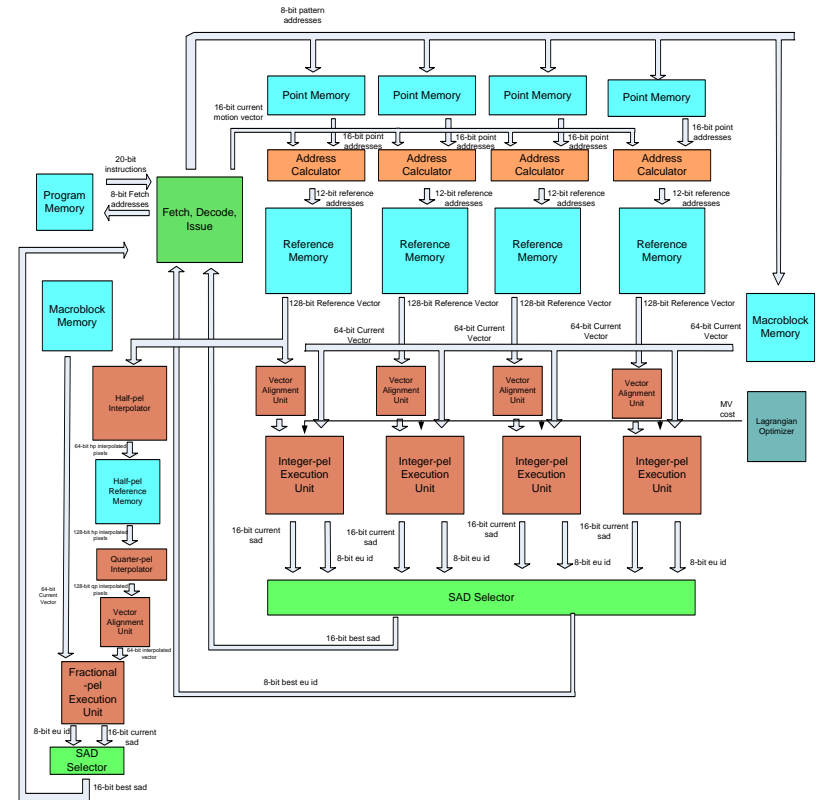
The reconfigurable processor

- Advanced features such as rate distortion optimization using Lagrangian techniques.
- Multiple motion vector candidates allowed.
- Multiple sub-partition sizes allowed.
- Multiple reference frames allowed.
- Can do fractional pel motion estimation that can be used for the H.264 standard.

Simple and complex configurations



Simple (1 integer pel unit)



Complex (4 int. pel units, 1 frac. pel unit, Lagrangian optimizer)

Processor performance and complexity evaluation

Processor Configuration	Speed (cycles/MB, frames/second)	FPGA size (LUTs, slices)	Memory (BRAMS)
Base configuration (1 integer-pel execution unit)	625 cycles/MB, 39 fps	2289 LUTs, 1300 slices	21 BRAMS (2 ref. areas, 112×128 pixels)
Complex configuration (4 integer-pel execution units)	234 cycles/MB, 104 fps	7074 LUTs, 3703 slices	72 BRAMS (2 ref. areas, 112×128 pixels)

Video sequence: 1080p *crowdrun* from SVT HD multi format test set

FPGA part: Virtex-4 SX35, 200 MHz clock frequency

Algorithm: 6-point hexagonal search (up to 8 steps), then 8-point square

Designing block-matching algorithms

- Estimo C: high-level language for search algorithms.
- Compiler targets the reconfigurable processor.
- No need to know how hardware works.
- Compiled program works across all configurations.

```
s = 8; // initial step size
check(0, 0);
check(0, s);
check(0, -s);
check(s, 0);
check(-s, 0);
update;
do {
    s = s / 2;
    for (i = 1 to 5 step 1) {
        check(0, s);
        check(0, -s);
        check(s, 0);
        check(-s, 0);
        update;
        #if (WINID == 0)
            #break;
        }
    } while (s > 1);
    for (x = -0.5 to 0.5 step 0.25)
        for (y = -0.5 to 0.5 step 0.25)
            check(x, y);
    update;
```


Cycle-accurate simulator

- Analysing processor configurations on hardware takes time.
- Using simulator, no need for synthesizing hardware and configuring board.
- No hardware required for evaluation of processor.



The IDE

SharpEye Studio 2008 - A complete framework for the Development of Motion Estimation Algorithms

File Edit Build Help

Project Explorer

Solution Files

- Project files
- Estimo Source Files
 - D:/projects/hex/hex.est
- Output Files
 - Assembly.asm
 - patterns.bin
 - program.bin

```

Pattern(quarter) (
    check(0.25, 0)
    check(0, 0.25)
    check(-0.25, 0)
    check(0, -0.25)
)

check(zero);
for(i = 1 to 8 step 1) (
    check(hex);
    #if(WINID == 0)
        #break;
    )
check(square);
for(i = 1 to 2 step 1) (
    check(half);
    #if(WINID == 0)
        #break;
    )

```

Cycle Accurate Model

Motion-estimation search configuration

Program memory: D:/projects/hex/estimo.output/program.bin Browse...

Points memory: D:/projects/hex/estimo.output/patterns.bin Browse...

Full-pel execution units: 2

Sub-pel execution units: 1

Smallest partition: 16x16

☒ Enable Motion Vector cost optimization

☒ Enable Motion Vector candidates

Video data

Video file: D:/test_sequences/1080p/pedestrian_area.yuv Browse...

Resolution: 1920 x 1080

Maximum number of frames: 50

QP (0 is lossless): 26

Reference frames: 1

Results

Processor configuration:

Label: Cfg 24

Full-pel units: 2

Sub-pel units: 1

Smallest partition: 16x16

MV cost optimization: enabled

MV candidates: enabled

Logic cells: 11287

Results:

Bit rate (kbit/s): 6793.27

PSNR (dB): 41.3

FPS: 20.7457

Cycles / macroblock: 1181.44

Energy / macroblock (nJ): 20.9706

Full- and sub-pel in parallel:

FPS: 31.8295

Cycles / macroblock: 770.033

Energy / macroblock (nJ): 13.6681

Video data:

Video file: D:/test_sequences/1080p/tractor.yuv

Resolution: 1920x1080

Frames processed: 50

QP (0 is lossless): 26

Reference frames: 1

tractor

Processor configuration:

Label: tractor

Program memory: D:/projects/hex/estimo.output/program.bin

Point memory: D:/projects/hex/estimo.output/patterns.bin

Full-pel units: 1

Sub-pel units: 1

Smallest partition: 16x16

MV cost optimization: enabled

MV candidates: enabled

Logic cells: 9732

Results:

Bit rate (kbit/s): 12398.4

PSNR (dB): 39.171

FPS: 15.7436

Cycles / macroblock: 1556.81

Energy / macroblock (nJ): 22.3792

Full- and sub-pel in parallel:

FPS: 26.1083

Cycles / macroblock: 938.773

Energy / macroblock (nJ): 13.4949

Fps against bit rate for different sequences

Frames / second (parallel)

Bit rate (kbit/s) x 10³

station blue sky

sunflower

rush hour

pedestrian

pedest 2 tractor

Plot title: Fps against bit rate for different sequences

X-axis: Bit rate

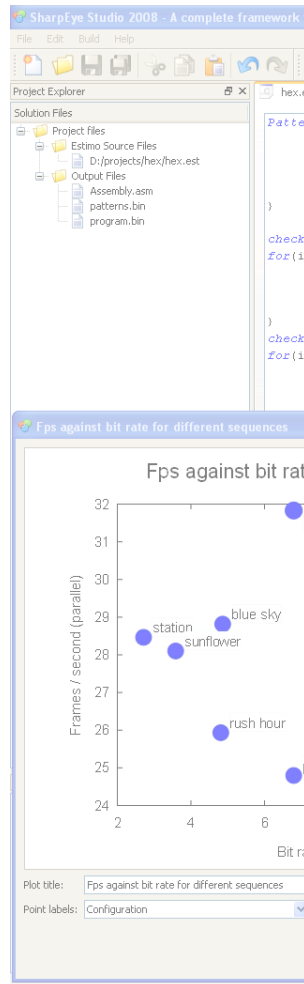
Point labels: Configuration

Y-axis: Frames / second (parallel)

Area: Logic cells

Export... Print...

The IDE



Cycle Accurate Model

Motion-estimation search configuration

Program memory: D:/projects/hex/estimo.output/program.bin Browse...

Points memory: D:/projects/hex/estimo.output/patterns.bin Browse...

Full-pel execution units: 2

Sub-pel execution units: 1

Smallest partition: 16x16

☒ Enable Motion Vector cost optimization

☒ Enable Motion Vector candidates

Video data

Video file: D:/test_sequences/1080p/pedestrian_area.yuv Browse...

Resolution: 1920 x 1080

Maximum number of frames: 50

QP (0 is lossless): 26

Reference frames: 1

Results

Processor configuration:		Results:	
Label:	Cfg 24	Bit rate (kbit/s):	6793.27
Full-pel units:	2	PSNR (dB):	41.3
Sub-pel units:	1	FPS:	20.7457
Smallest partition:	16x16	Cycles / macroblock:	1181.44
MV cost optimization:	enabled	Energy / macroblock (nJ):	20.9706
MV candidates:	enabled	Full- and sub-pel in parallel:	
Logic cells:	11287	FPS:	31.8295
Video data:		Cycles / macroblock:	770.033
Frames processed:	50	Energy / macroblock (nJ):	13.6681
QP:	26		
Reference frames:	1		

Run Stop New Plot Table

Model

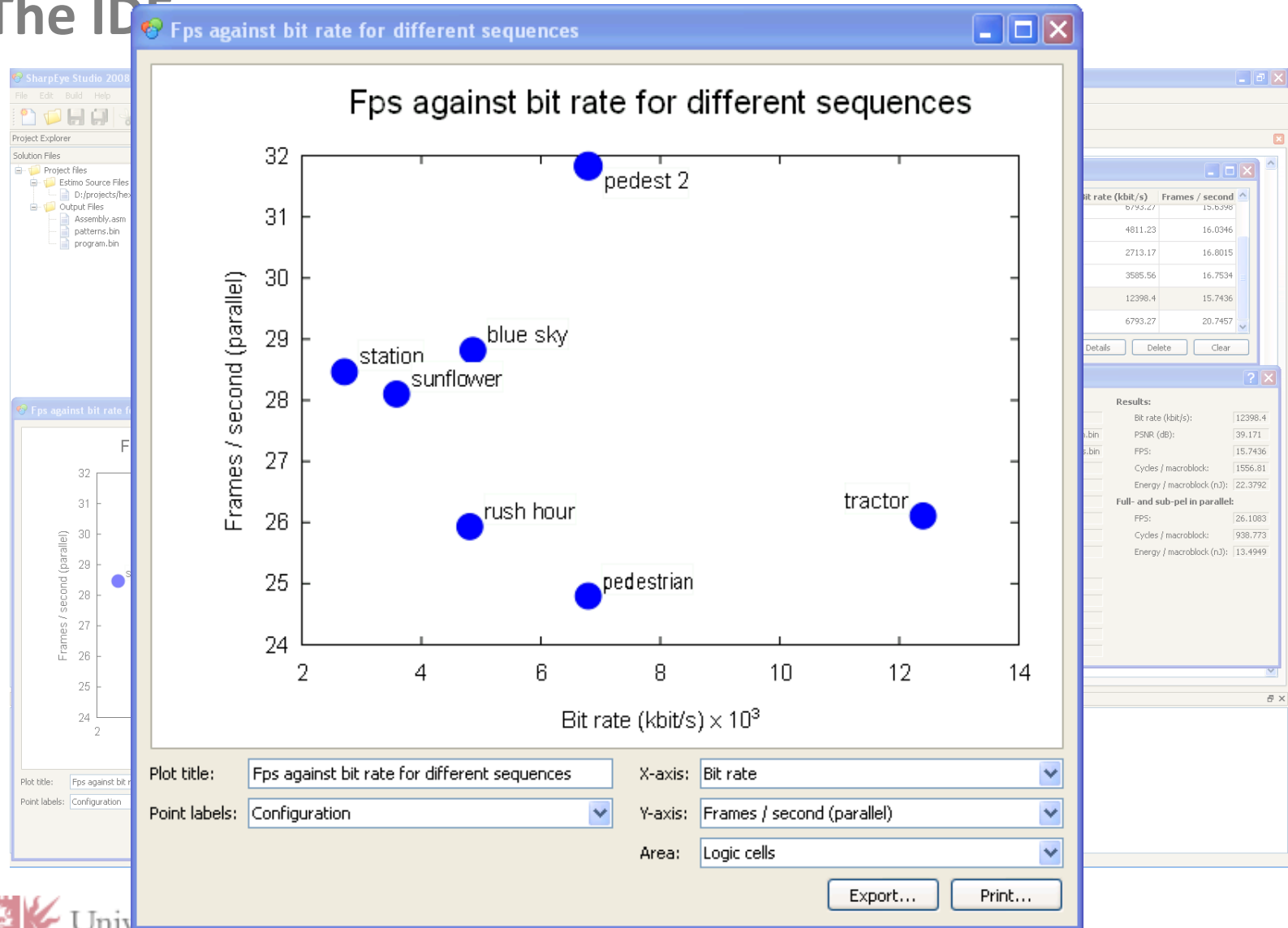
PSNR (dB)	Bit rate (kbit/s)	Frames / second
41.3	6793.27	20.7457
41.874	4811.23	16.0346
40.705	2713.17	16.8015
42.326	3585.56	16.7534
39.171	12398.4	15.7436
41.3	6793.27	20.7457

Export configuration... Details Delete Clear

Results:

Bit rate (kbit/s):	12398.4
PSNR (dB):	39.171
FPS:	15.7436
Cycles / macroblock:	1556.81
Energy / macroblock (nJ):	22.3792
Full- and sub-pel in parallel:	
FPS:	26.1083
Cycles / macroblock:	938.773
Energy / macroblock (nJ):	13.4949

The IDE



The IDE

The image shows the SharpEye Studio 2008 IDE interface. The main window displays the 'Cycle Accurate Model' table, which lists configurations and their performance metrics. The 'tractor' configuration is highlighted, and its details are shown in the 'tractor' window. A plot titled 'Fps against bit rate for different configurations' is also visible, showing FPS values for various configurations.

Cycle Accurate Model

Configuration	PSNR (dB)	Bit rate (kbit/s)	Frames / second
pedestrian	41.3	6793.27	15.6398
rush hour	41.874	4811.23	16.0346
station	40.705	2713.17	16.8015
sunflower	42.326	3585.56	16.7534
tractor	39.171	12398.4	15.7436
pedest 2	41.3	6793.27	20.7457

tractor

Processor configuration:

Label: tractor

Program memory: D:/projects/hex/estimo.output/program.bin

Point memory: D:/projects/hex/estimo.output/patterns.bin

Full-pel units: 1

Sub-pel units: 1

Smallest partition: 16x16

MV cost optimization: enabled

MV candidates: enabled

Logic cells: 9732

Results:

Bit rate (kbit/s): 12398.4

PSNR (dB): 39.171

FPS: 15.7436

Cycles / macroblock: 1556.81

Energy / macroblock (nJ): 22.3792

Full- and sub-pel in parallel:

FPS: 26.1083

Cycles / macroblock: 938.773

Energy / macroblock (nJ): 13.4949

Video data:

Video file: D:/test_sequences/1080p/tractor.yuv

Resolution: 1920x1080

Frames processed: 50

QP (0 is lossless): 26

Reference frames: 1

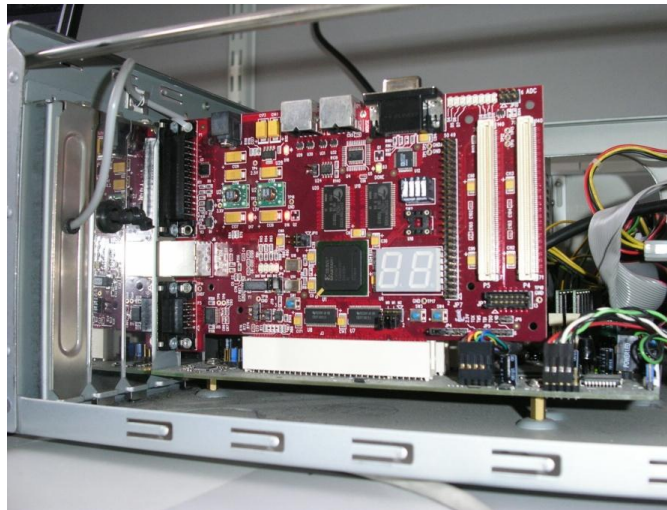
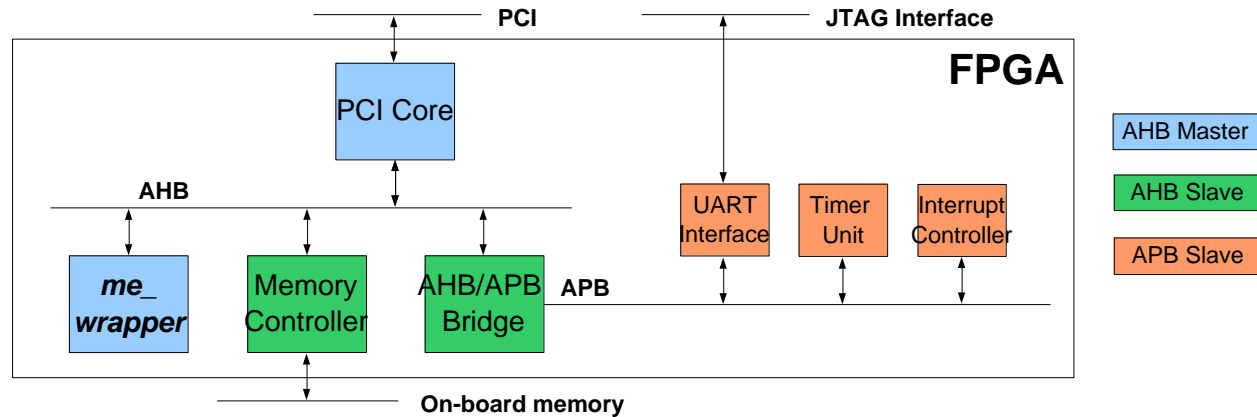
Plot:

Plot title: Fps against bit rate for different configurations

Point labels: Configuration

The plot shows FPS values for various configurations. The 'station' configuration is highlighted with a red dot, showing a FPS of approximately 28.5.

Prototype implementation



Summary

- Programmable and configurable processor supports HD motion estimation (supports H.264, MPEG-4, MPEG-2, VC-1, AVS).
- Motion Estimation Processor: <http://www.opencores.org/>
- Estimo C compiler for easy development of proprietary block-matching algorithms.
- FPGA-based PCI demonstration board available.
- Cycle-accurate simulator for quick evaluation and design space exploration.
- SharpEye IDE: <http://sharpeye.borelspace.com/>